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J. B. Schroeder	Patricia Mauley
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Development of an Integrated Diagnostic Strategy to Support Autonomic Logistics

Gary M. Smith, USAF Wright Lab
J. B. Schroeder, USAF Wright Lab
Sergio A. Navarro, TRW Space & Electronics Group
Douglas G. Haldeman, TRW space & Electronics Group

1. Introduction

1.1 JSF Support

The Joint Strike Fighter (JSF) is addressing the question of how the United States will maintain battlefield superiority with airpower in the 21st century. The focus of the program is affordability – reducing the development cost, production cost and cost of ownership of the JSF family of aircraft. In addition to affordability as a "pillar" of the JSF program, three additional pillars have been established: survivability, lethality, and supportability/deployabiltiy. These four pillars have established the foundation for the design and development of the JSF platform. The key to providing an affordable approach to supportability and depoyability lies in the concept of autonomic logistics. This paper focuses on the contribution of diagnostics and its relationship to autonomic logistics.

1.2 Current Situation

The current operational environment is increasing in complexity while the cost to maintain weapon systems has increased and the availability of resources has decreased. Many resources are spent in chasing faults that either do not exist or exhibit themselves only in peculiar and non-repeatable situations. In today's environment, with a mixed set of technology and aircraft generations, most system's diagnostic capability is focused in four areas: on-board, flight line, intermediate shop and depot. Current diagnostic systems generally work in a stove pipe fashion with information and tools developed expressly for a specific application. This results in the classic Cannot Duplicate / No Fault Found and Retest OK (CND/NFF & ReTOK) problem. In addition, resources for each diagnostic environment are designed at a different time by a different set of engineers and, except for on-board Built In Test (BIT), are designed after the aircraft design is fundamentally complete. Consequently, the support of diagnostics is further segmented by both time and technology. There is a further complication for the Joint Strike Fighter in that it will be used by multiple organizations with vastly differing philosophies of maintenance and data management.

1.3 System Needs

In order to significantly improve the affordability and supportability of the JSF, JSF diagnostics (including prognostics and health management) must be an integral and integrated part of the overall design. The inherent supportability of a system is influenced by the balance between reliability and diagnostics during the early stages of its development. There are well established tools and processes to evaluate the impact of reliability on total weapon system support. However, tools have not yet been developed to relate both reliability and diagnostic coverage to life cycle implications of the weapon system. Tools are required early in the development process to analyze the impact of design decisions relating to on-board, flight line, intermediate and depot diagnostic support. These tools allow tradeoffs to be performed between performance, supportability and affordability alternatives. In addition, the ability to evolve to an autonomic support concept will depend not only on diagnostics, but also on communications between the various diagnostic elements and the information sources that will support the weapon system. The impact of cradle-to-grave supportability design and the tools to evaluate diagnostic and reliability contributions are implicit in the autonomic logistics approach.

1.4 Overview

This paper will address the relationship between diagnostics and a fully integrated support concept for the future. It will illustrate how the information obtained from diagnostics and its ready access by critical operational elements are key requirements of a autonomic logistic support system.

2. JSF Autonomic Support Concept

2.1 Operation Support Concept of Today

In today's operational environment, each service has unique solutions to its individual logistics support needs. All campaigns are, by definition, "joint" and require coordinated efforts during operations. The logistics support systems of the services, however, contain unique support solutions and are not coordinated. Each service must independently move their support materials into the theater by air or sea transportation. This makes for a very intense and uncoordinated movement of materials before the campaign begins. This method of forward stockage of materials is effective, but it is inefficient, contains redundancies, and introduces a undesirable time lag. This severely limits the ability to get operations started when forces arrive.

The current logistics support system is an infrastructure that is reactive versus proactive. This type of system does not anticipate imminent demands for support materials or personnel. It knows what happened yesterday, but it is inadequate in anticipating the demands for tomorrow's needs. Due to the lack of prognostics and health management data, additional parts and personnel resources are required to perform maintenance to

achieve an acceptable mission capable rate and reduce the risk of in-flight failure. The logistics system of today is not able to think or act on its own. It is very labor intensive in making decisions and ordering support materials; it cannot translate operational and maintenance data into a decision or action. It requires intense human interaction to make decisions at every level of indenture. As a result, the emphasis has been on trying to make the support system respond to our needs rather than concentrating on fixing aircraft and keeping the sortie generation rate high. This is especially important early in the campaign when air superiority is crucial.

2.2 Autonomic Support Concept

The JSF autonomic support concept is more than the typical number of people, equipment, spares, bombs, bullets, and life support considerations. The autonomic support concept is analogous to the autonomic nervous system that directs the body to "breath in, breath out" without being told to do so. The autonomic logistics infrastructure responds with minimal human interaction -- making decisions at each step of the sortie generation cycle. For the autonomic logistics support concept to work, there must be a stimulus to trigger the system. The diagnostic system being developed for the JSF platform is the main stimulus that triggers a spontaneous response that sets the autonomic logistic support system in motion.

One of the unique features of this system is the timing of the stimulus provided to the autonomic support system. In present systems, the aircraft is debriefed only after return from the mission; tools and equipment needed to ready the aircraft for the next mission must be ordered, acquired, and rolled out to perform maintenance and service. An autonomic support system can be stimulated prior to an aircraft's return from the mission; tools and equipment can be readied for use before the aircraft lands. This greatly reduces the turnaround time. Also, in present systems, the human must rely on multiple, diverse sources of information from the aircraft and pilot in determining problems and making decisions on corrective actions. The autonomic system relies on an integrated report from aircraft diagnostics that minimizes incorrect maintenance actions and decreases support response requirements.

There are several other advantages in getting ready to service the aircraft prior to landing. The on-board diagnostic system may report a fault that the technician is not familiar with. The autonomic support system provides the capability for maintenance rehearsal prior to actually performing the maintenance event. At the same time, the spare part(s) are being ordered by the autonomic support system to be at the ramp or carrier deck along with the technician when the aircraft arrives. The technician is armed with both the spare part and the experience to perform diagnostics and repair the malfunctioning part of the system. The aircraft is returned to "fully mission capable" status and ready for the next mission – thus maintaining a high sortie generation rate.

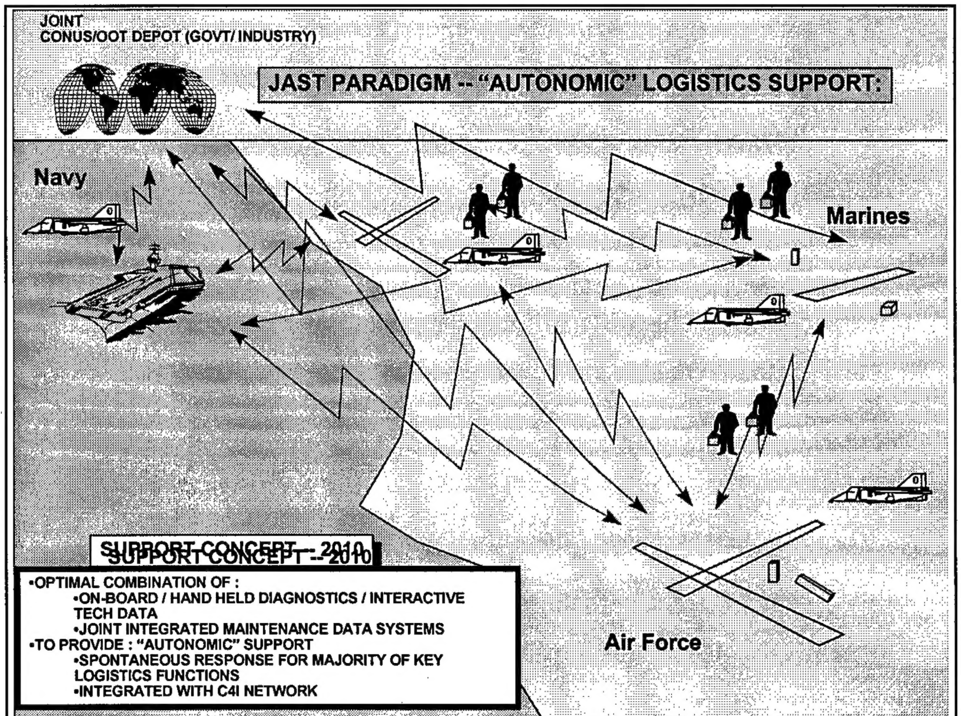

Figure 2.1 Future Autonomic System

2.3 The Diagnostic System Characteristics

What are the diagnostic system characteristics that will enable the autonomic support system? The diagnostic system must be designed as part of the systems engineering process -- keeping in perspective the level of reliability, diagnostics, and maintainability that the system will need and can afford as well as how the solution fits into the overall diagnostic architecture. These variables will yield the inherent support characteristics of the system. The system must be able to diagnose and fault isolate to a low enough level to tell the autonomic support system what the problem is and what will be required to correct it.

Prognostics and health management, the capability of anticipating when a failure will occur, is important in preventing critical failures and allowing the autonomic system to schedule planned maintenance. Prognostics is especially key in the propulsion system. In the case of the JSF, the reliability of the propulsion system must be better than that of the F-18 with a single engine. This will require the propulsion system to be equipped with a prognostic capability that will enable the aircraft to leave the end of the carrier deck with the assurance that the mission will be successfully completed.

Another key characteristic of the overall diagnostic concept and the autonomic logistics support system is the JSF Joint Distributed Information System (JDIS). The JDIS will

support real-time information flow between all of the elements of the integrated diagnostic architecture. (See Figure 2.2) Diagnostic data acquired from in flight and ground support environments will be available for use in diagnosing and performing fault analyses at all levels of maintenance.

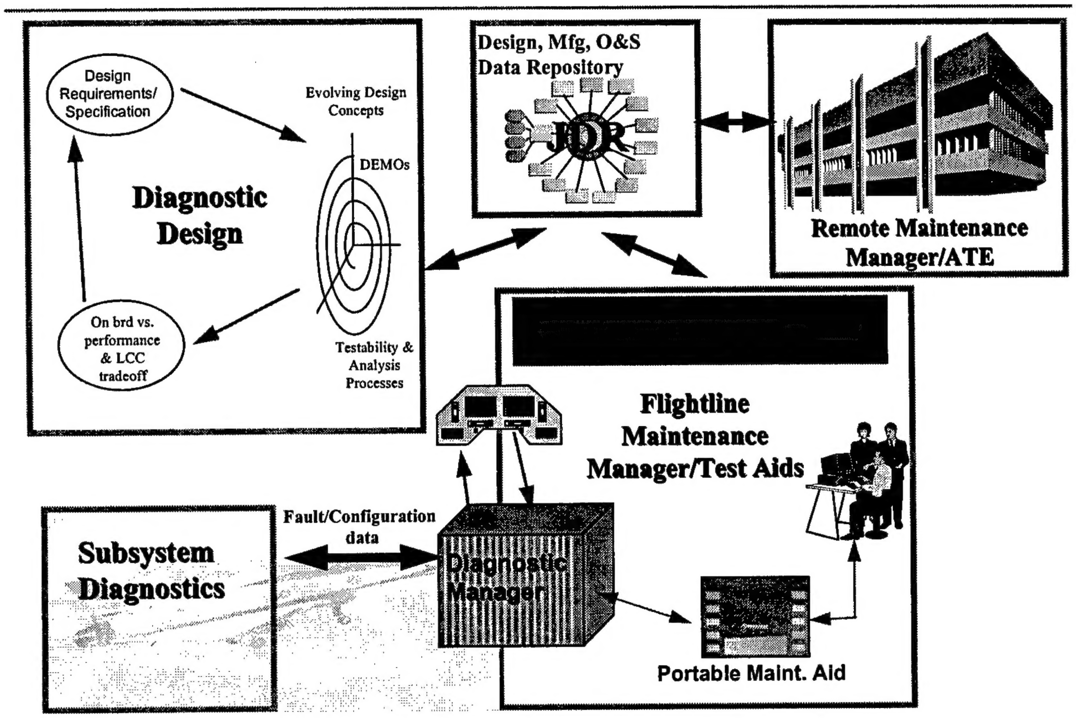

Figure 2.2 ASID Architecture Scope

2.4 JSF Integrated Diagnostics

The Advanced Strike Integrated Diagnostic (ASID) effort defined and designed an advanced integrated diagnostic concept that would provide improved reliability and maintainability in major strike weapon systems. Its goal is to improve supportability with an integrated application of diagnostic technologies to reliably achieve 100% fault coverage through a mixture of embedded and ground based diagnostic techniques. Architecture, in this context, consists of a comprehensive, consistent set of functions, information, and information flow according to which systems may be organized, designed, and constructed. This architecture spans the entire life cycle of the integrated diagnostic system (design through O&S), and encompasses all on board and off board systems.

The ASID open architecture development process addresses the cost, schedule, benefits, resources, interrelationships, and tasks necessary to successfully demonstrate this integrated diagnostic concept in later JSF program phases. The ASID concept includes diagnostic and prognostic techniques and technologies, diagnostic sensor technologies,

diagnostic design tools and processes, joint maintenance data systems, and a diagnostic architecture for the total aircraft. The diagnostic technologies and processes addressed are applicable to both Fault Detection (FT) and Fault Isolation (FI) as well as diagnostic data capture. This data resource is then made available to all levels of fault isolation as well as for failure analysis and fault treatment. These technologies and processes support diagnostic strategies that provide system level coverage for all aspects of an advanced weapon system and enable the approach to autonomic logistics.

The vision for integrated diagnostics in the environment of autonomic logistics relies on the connected nature of the architecture. For every fault detected there is a sequence of events that assures quick return to service of the vehicle, comprehensive data flow to stake holders in maintenance, operations and logistics, and data storage for subsequent analysis. The integration process begins with tool availability during design that aids in analysis of fault implications. The process continues through onboard systems design to logistic requirements based on parts availability in the projected operational scenarios. The process includes the analysis of costs of doing business for the entire life cycle.

3. Summary

Autonomic logistics is a goal that can only be reached when supportability and diagnostics is addressed early in the development from both a performance and life cycle cost perspective. The integrated diagnostic approach presented here has evolved from studies of current and developing diagnostic and communication technologies. The development process involved contributions from all elements of the supportability community, government and contractors, designers, researchers, logisticians and maintainers. Autonomic logistics is not merely a goal but an achievable concept that can be employed for the Joint Strike Fighter and serve as a road map to mature and integrate technologies for aircraft supportability.